

# **Response and Nutrient Uptake in Bermudagrass Treated with Aquatrols Surfactant ACA 1848 in the Desert Southwest**

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## **ABSTRACT**

*Aquatrols surfactant ACA 1848 was applied to Tifway 419 hybrid bermudagrass at rates of 12 or 48 ounces/acre and evaluated for turfgrass growth, performance, and nutrient uptake. Soil samples collected during the growing season were analyzed for inorganic nitrogen (ammonium and nitrate). Only on the last sampling date only (September 29), the soil nitrate-nitrogen level was slightly higher in the untreated control than in other plots. Otherwise, soil nitrogen levels did not differ among treatments.*

*Growth measurements and visual ratings did not differ among treatments at any time during the growing season, indicating that surfactant treatments did not affect either of these parameters. Leaf clippings collected throughout the growing season were analyzed for total nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, sodium, boron, copper, iron, manganese, and zinc. With only one exception, differences in nutrient content among treatments were statistically non-significant at the 5% significance level. That exception occurred on August 18 when the turfgrass treated with surfactant at the 12 oz/a/wk level had less zinc than turfgrass in the 0 or 48 oz/a/wk treatments. There was a noticeable, but non-significant trend, observed as follows; the highest level of surfactant treatment (48 oz/a/wk) resulted in the highest tissue levels of phosphorus, potassium, sulfur, sodium, boron, and copper in samples collected on July 21 (day 203), August 4 (day 217), and September 1 (day 245).*

*Calcium, magnesium, and iron levels were highest in this treatment on August 4, but these differences were extremely small and always statistically non-significant and this trend was not observed on other sampling dates. There were no consistent rate trend responses (i.e. where the higher level of surfactant treatment produced a greater response than the lower rate) throughout the test. On all sampling dates, the untreated control contained more manganese than either of the surfactant treatments; the differences were not statistically significant and were not rate related.*

*In this field study, there were no turfgrass responses, either positive or negative, that we could attribute to Aquatrols ACC 1848 applied at 12 and 48 oz/a weekly. The magnitudes of response differences observed in this study were not large enough to identify statistically significant differences.*

## **Introduction**

A field study was conducted to evaluate the effects of a specific Aquatrols surfactant (ACA 1848) on nutrient uptake and general performance of turfgrass in the desert southwest. To that end, a protocol was developed and approved by Aquatrols. The experiment consisted of three treatments: a control with no surfactant applied, the Aquatrols surfactant at rates of 12 and 24 ounces of product per acre applied each week during the growing season. These treatments were applied in a randomized complete block design with four replications. Nutrients were applied once per month, according to standard practices employed in our area. Grass clippings were collected twice monthly (one week and three weeks after fertilizer application), dried, weighed, and analyzed for nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, boron, copper, iron, manganese, and zinc content. All plots were visually rated for turfgrass color, density, quality, and texture twice monthly. Complete soil analysis was conducted once at the beginning of the study. Soil inorganic nitrogen (ammonium and nitrate) was analyzed twice monthly, on the tissue sampling dates.

## **PROCEDURE**

The experiment was initiated June 17, 2004 at the University of Arizona, Karsten Turfgrass Research Facility on a six year old field of bermudagrass var. Tifway 419 (*Cyanodon dactylon x transvaalensis*). Plots measured 5 ft by 12 ft each. The first surfactant application was made on June 17, 2004 and the final application on October 7, 2004.

Surfactant was applied weekly at three rates, 0, 12, and 48 oz surfactant/acre for 17 weeks. A CO<sub>2</sub> backpack sprayer with a three nozzle boom with 20 inch spacing was used for all applications. Over spray (drift between plots) was controlled by placing cardboard on the borders of the plots. After application, the treatments were hand watered into the soil. The initial fertilization of the plots was done with the third surfactant application, and every four weeks following for a total of four applications (application dates were July 1, July 29, August 26, and September 23). All plots were fertilized at the same rate (0.80 lb N 1000 ft<sup>-2</sup> per month applied in the form of ammonium nitrate) using a three foot-wide Gandy drop spreader. The plots were first traversed along a north-south line followed by an east-west line to give uniform coverage.

Grass clippings were collected every two weeks beginning one week after the first fertilization. Clippings were taken using a John Deere 2653A triplex reel mower with 26 inch reels set to a cutting height of 5/8 inch with a catch basket placed on the left reel of the mower which was run down the center of each plot. On one occasion only (September 1) a John Deere 2653 mower was used. Therefore clipping weights for this date are not directly comparable to those collected on other dates, but between treatment comparisons for this date are valid. The grass was then dried in an oven at 65° C, weighed, and ground to < 30 mesh. Total nitrogen was determined by combustion with a nitrogen analyzer. Calcium, magnesium, sodium, potassium, phosphorus, sulfur, boron, zinc, iron, manganese and copper were measured in acid digests by ICP (inductively coupled plasma spectrometry).

Soil samples were collected before the initial application of fertilizer. All samples were air dried and then ground to pass a 2 mm sieve. Soil pH and EC (electrical conductivity) were measured in 1:1 (soil:water) extracts using appropriate electrodes. Inorganic nitrogen was extracted using 1.0 M KCl and analyzed on a continuous flow analyzer. Nitrate was analyzed using the cadmium reduction method (Maynard and Kalra, 1993) while ammonium ( $\text{NH}_4^+$ ) utilized the salicylate-hypochlorite method (Mulvaney, 1996). Available calcium, magnesium, sodium, and potassium were measured in 1 N  $\text{NH}_4\text{OAc}$  extracts by ICP (Simard, 1993). Extractable metals (zinc, iron, manganese, and nickel) were determined in 2:1 (solution:soil) 0.005 M DTPA extracts followed by ICP analysis (Liang and Karamanos, 1993). Available phosphorus was determined in a 0.5 N  $\text{NaHCO}_3$  extract followed by measurement on a flow analyzer (Kuo, 1996). Extractable boron and sulfate sulfur ( $\text{SO}_4^{2-}$ ) were measured in hot water extracts by ICP (Hanks et al., 1997). Cation exchange capacity (CEC) was calculated by summing exchangeable cations. Bi-weekly soil samples were collected for the remainder of the study on the same days as the plant samples. These samples were processed in the same manner as above, however were only analyzed for inorganic nitrogen (nitrate and ammonium).

All data were statistically analyzed using standard Analysis of Variance (ANOVA) procedures with SAS for Windows Release 9.0 (SAS Institute, 2002).

## RESULTS

### Soil Analyses

Soil samples were collected prior to the initiation of the study, and comprehensive soil analyses were conducted. The purposes of these analyses were three-fold. This set of analyses was used to ensure that there were no differences in soil among the various plots or treatments. As can be seen in Table 1, the results of these analyses indicate that the soil in the test site was relatively uniform. The second purpose of this sampling was to make sure soil properties (nutrient levels, salts, etc.) were typical of values commonly seen in our area. The data in Table 1 indicate that all values were within normal ranges and that this soil was not sodic. The third purpose was to provide a baseline such that if significant differences in plant nutrient uptake were observed between treatments, we could collect soil samples at the end of the study to evaluate changes attributable to experimental treatments.

Soil nitrogen was measured throughout the study. Nitrogen is taken up by plants in two forms, nitrate ( $\text{NO}_3^-$ ) and ammonium ( $\text{NH}_4^+$ ). Most plants take up a combination of these two forms of nitrogen, but many prefer one form over the other. Ammonium tends to be retained in soils, whereas nitrate is easily moved downward through the soil profile with leaching water, and can be lost by moving below the active root zone. Conversion from ammonium to nitrate occurs via biological transformation in soil. This process is sensitive to soil conditions such as temperature, moisture, and salinity. It also can be affected by herbicides, insecticides, and other agricultural chemicals. Therefore, we collected periodic samples to evaluate effects of applied surfactant on soil nitrogen form as well as quantity. Results are shown in Figures 1 and 2, and Tables 2 and 3.

Both nitrate-nitrogen and ammonium-nitrogen levels increased between day 189 and 203. This may be due to increasing soil temperature, as ammonium is more rapidly converted to ammonium in warmer soils. Nitrate levels generally increase following fertilizer applications (made on Julian day 183, 211, 239, and 267). The one exception is that soil nitrate levels did not rise in soil samples collected on day 189, even though fertilizer was applied the previous week. We believe this is because excess irrigation was applied during this one week period to establish turfgrass in an adjacent experiment, washing nitrate from the sampled soil. Statistical analyses (Tables 2 and 3) indicate that soil nitrogen levels were not affected by treatments, with the lone exception of soil nitrate-nitrogen on the final sampling date. In this case, the nitrate-nitrogen levels do not follow treatment levels, and are probably not attributable to surfactant treatments.

### Bermudagrass Grass Clipping Weight

Clipping weights are shown in Table 4 and in Figure 3. The day of data collection is noted as Julian date (day of the year). Treatments are shown in the legend at the right side of the figure. Statistical analyses are shown in the table and significance of treatment effects is given (effects were tested at significance levels  $P=0.01$  and  $0.05$ ). The same data presentation format is used for all subsequent data.

Clipping weights are given in grams per square meter and can be used for a relative comparison of above-ground leaf growth. Note that clippings collected on September 1 (Julian date 245) were collected with a different mower than clippings on other dates, and can not be compared to other dates. Clipping weights among treatments can still be compared for each date. No significant differences were observed in clipping weights on any of the data collection dates. On several dates (189, 217, 245, and 259) the 48 oz/a/wk treatment yielded the greatest clipping weights, but the differences were not statistically significant. Furthermore, if observed differences reflected a response due to surfactant application treatments, a trend for yields in the order 48 oz/a/wk > 12 oz/a/wk > control might be expected, but no such trend was observed.

### Visual Analyses

Bermudagrass was visually rated for turfgrass color, density, quality, and texture twice each month. All turfgrass received acceptable rating scores for each of the rated parameters throughout the growing season. At no time were there any visually discernable differences between turfgrass in individual plots, therefore data are not presented.

### Bermudagrass Total Leaf Nitrogen

Total leaf nitrogen concentrations are shown in Figure 4 and Table 5. No significant differences among treatments were observed. Additionally, no consistent trends were observed between treatments, indicating that the application of surfactants did not change nitrogen uptake in bermudagrass. Sufficient levels of nitrogen in bermudagrass are considered to be between 3.0 to 5.0% (Jones et al., 1991), signifying that the grass in this test was adequately supplied with nitrogen.

### Bermudagrass Leaf Phosphorus

Phosphorus concentrations in bermudagrass clippings are shown in Figure 5 and Table 6. No statistically significant differences were observed. The highest tissue phosphorus levels were found in the 48 oz/a/wk surfactant treatment on three sampling dates (days 203, 217, and 245), however, these were not statistically greater than phosphorus levels in clippings from the control plots which did not receive surfactant. The sufficiency range for bermudagrass tissue phosphorus is 0.15 to 0.50% (Jones et al., 1991), which indicates that the bermudagrass in the current test was adequately supplied with phosphorus.

### Bermudagrass Leaf Potassium

Potassium concentrations in collected bermudagrass clippings were not significantly affected by surfactant treatments (Figure 4 and Table 5). As with phosphorus, the highest potassium concentrations on days 203, 217, and 245 were highest in the 48 oz/a/wk treatment, but these differences were not statistically significant. Potassium levels were slightly below optimum (1.00 to 4.00%, Jones et al., 1991) on the first sampling date. Levels increased thereafter, but were still at or slightly below the normal range for the rest of the growing season.

### Bermudagrass Leaf Calcium

Leaf tissue calcium levels are shown in Figure 7 and Table 8. Calcium levels were statistically unaffected by surfactant treatments. There were no apparent surfactant rate trends for calcium throughout the test. Calcium is considered sufficient if between 0.50 and 1.00% (Jones et al., 1991). Most of the recorded values fell within this range.

### Bermudagrass Leaf Magnesium

Leaf tissue magnesium levels are presented in Figure 8 and Table 9. No significant differences were recorded. As with phosphorus and potassium, slightly higher (but statistically non-significant) levels were found in samples collected on days 217 and 245. The magnesium sufficiency range is from 0.13 to 0.50% (Jones et al., 1991). Mid-season values fell slightly below the minimum of this range.

### Bermudagrass Leaf Sulfur

Leaf tissue sulfur levels are presented in Figure 9 and Table 10. No statistically significant differences were recorded and there were no rate trends observed. However, as with phosphorus and potassium, slightly higher (but statistically non-significant) levels were seen in samples collected on days 203, 217, and 245. Sulfur is considered sufficient when between 0.15 and 0.50% (Jones et al., 1991). All measured values fell within this range.

### Bermudagrass Leaf Sodium

Sodium levels in bermudagrass clippings are presented in Figure 10 and Table 11. No statistically significant differences were found. However, as with phosphorus, potassium, and sulfate-sulfur, slightly higher (but statistically non-significant) levels were observed in samples from days 203, 217, and 245. Sodium is not an essential plant nutrient, so no standards are available.

### Bermudagrass Leaf Boron

Boron levels in bermudagrass leaf tissue are presented in Figure 11 and Table 12. For each clipping date, there were no statistically significant differences. The highest boron levels were found in the treatments that received the highest level of surfactant on days 203, 217, and 273, however, as with the previously discussed nutrients, all differences were statistically non-significant. All of the leaf boron levels fell within the sufficiency range (6 to 30 ppm, Jones et al., 1991).

### Bermudagrass Leaf Copper

Copper levels in bermudagrass leaf tissue are presented in Figure 12 and Table 13. No statistically significant differences were found. The highest boron levels were found in the treatments that received the highest level of surfactant on days 217 and 273, however, as with the previously discussed nutrients, all differences were statistically non-significant. The sufficiency range for copper in bermudagrass is 5 to 50 ppm (Jones et al, 1991), indicating that the bermudagrass in this trial had adequate levels of copper for optimum growth.

### Bermudagrass Leaf Iron

Bermudagrass leaf tissue iron levels are shown in Figure 13 and Table 14. No statistically significant differences were found. The iron sufficiency range for bermudagrass is 5 to 350 ppm (Jones et al, 1991). The levels in this study are somewhat higher, however, there is little or no research suggesting that higher levels of iron are deleterious to growth of bermudagrass or other turfgrass species. Particularly in calcareous soils such as those on which this study was conducted, iron deficiency is a prevalent problem. Therefore, high leaf iron values are not considered to be a problem.

### Bermudagrass Leaf Manganese

Figure 14 and Table 15 show bermudagrass leaf tissue manganese levels. No statistically significant differences were found. Manganese levels in the turfgrass treated with surfactant always had lower manganese levels than untreated turfgrass, but all differences were non-significant. It does not appear that the surfactant treatments were responsible for a reduction in leaf manganese levels, because manganese concentrations were generally greater in plots receiving the higher level of surfactant (48 oz/a/wk) than in those receiving the lower surfactant level (12 oz/a/wk).

The manganese sufficiency range for bermudagrass is 25-300 ppm (Jones et al, 1991). All levels measured in the current study fell within this range.

#### Bermudagrass Leaf Zinc

Figure 15 and Table 16 show bermudagrass leaf tissue zinc levels. Zinc levels were higher in the untreated control and the 48 oz/a/wk treatments on day 231. No other statistically significant differences were observed. All analyzed samples fell within the sufficiency range for zinc in bermudagrass of 20 to 250 ppm (Jones et al., 1991).

### SUMMARY

Aquatrols surfactant ACA 1848 was applied to growing bermudagrass at rates of 12 or 48 ounces/acre each week during the growing season. Turfgrass growth and performance, and nutrient uptake were studied.

Soil samples collected prior to the initiation of the study showed that the soil at the study site was relatively uniform, and that no differences existed between plots before treatments were made.

All soil nutrient levels were within normal ranges. Soil samples collected during the growing season were analyzed for inorganic nitrogen (ammonium and nitrate). On the last sampling date only (September 29), the soil nitrate-nitrogen level was slightly higher in the untreated control than in other plots. Otherwise, soil nitrogen levels did not differ among treatments.

Growth measurements and visual ratings did not differ among treatments at any time during the growing season, indicating that surfactant treatments did not affect either of these parameters. Leaf clippings collected throughout the growing season were analyzed for total nitrogen, phosphorus, potassium, calcium, magnesium, sulfur, sodium, boron, copper, iron, manganese, and zinc. With only one exception, differences in nutrient content among treatments were statistically non-significant at the 5% significance level. That exception occurred on August 18 when the turfgrass treated with surfactant at the 12 oz/a/wk level had less zinc than turfgrass in the 0 or 48 oz/a/wk treatments. There was a noticeable, but non-significant trend, observed as follows; the highest level of surfactant treatment (48 oz/a/wk) resulted in the highest tissue levels of phosphorus, potassium, sulfur, sodium, boron, and copper in samples collected on July 21 (day 203), August 4 (day 217), and September 1 (day 245). Calcium, magnesium, and iron levels were highest in this treatment on August 4. However, we emphasize that the observed differences among treatments were extremely small and always statistically non-significant. This trend was not observed on other sampling dates. Furthermore, if this trend was due to applied surfactant treatments, we might expect that the lower level of surfactant treatment (12 oz/a/wk) would also have slightly elevated nutrient levels. We did not observe such a trend. Therefore, it is impossible to attribute the observed trend to applied surfactants.

The most consistent trend observed was related to leaf manganese concentration. On every sampling date the untreated control contained more manganese than either of the surfactant treatments. Again, the differences were never statistically significant and the tissue manganese levels did not follow the level of surfactant applied (i.e. the 12 oz/a/wk treatment generally contained less manganese than did the 48 oz/a/wk treatment, which would not be expected if the surfactant was inhibiting manganese uptake or translocation into leaf tissue).

In this field study, there were no turfgrass responses, either positive or negative, that we could attribute to Aquatrols ACC 1848 applied at 12 and 48 oz/a weekly. The magnitudes of response differences observed in this study were not large enough to identify statistically significant differences. In order to show biological response to ACA 1848, future studies should include higher and/or multiple rates of surfactant. Furthermore, this test was conducted on a non-sodic, non-saline soil. In sodic soils that exhibit poor water infiltration due to lack of soil structure, responses to surfactants may be more likely.

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Table 1. Results of soil analyses from soil samples collected prior to treatment application.

Treatment	pH	EC	CEC	ESP	Free	PO <sub>4</sub> -P	K	Ca	Mg
		dS/m	meq/100g	%	Lime	parts per million			
Control	8.4	0.66	21.3	5.8	High	31	320	3400	268
12 oz/a/wk	8.4	0.63	21.0	5.6	High	30	300	3375	265
48 oz/a/wk	8.4	0.65	21.3	5.6	High	29	308	3425	265

Table 1. continued

Treatment	SO <sub>4</sub> -S	Na	B	Cu	Fe	Mn	Ni	Zn
	parts per million							
Control	50	283	0.63	3.9	18	17	0.23	3.2
12 oz/a/wk	47	273	0.64	4.0	22	18	0.26	3.3
48 oz/a/wk	49	275	0.66	4.2	19	18	0.28	3.5

Table 2. Soil nitrate-nitrogen levels (ppm) and statistical analysis.

Treatment	Julian Date							
	183	189	203	217	231	245	259	273
Control	1.04	1.21	3.35	3.03	1.82	2.70	2.11	2.47
12 oz/a/wk	1.40	1.00	2.95	3.13	2.04	3.12	2.54	2.77
48 oz/a/wk	1.77	1.32	2.68	3.06	1.79	3.03	2.01	2.20
Treatment	NS	NS	NS	NS	NS	NS	NS	**

\*\* = significant at p = 0.01

NS = Not Significant

Table 3. Soil ammonium-nitrogen levels (ppm) and statistical analysis.

Treatment	Julian Date							
	183	189	203	217	231	245	259	273
Control	5.84	3.16	3.57	2.89	2.45	1.88	1.61	1.48
12 oz/a/wk	6.28	2.92	3.12	2.56	2.26	1.68	2.02	1.34
48 oz/a/wk	5.89	3.40	3.16	3.15	2.60	1.69	1.77	1.28
Treatment	NS	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 4. Bermudagrass clipping dry weights (g/m<sup>2</sup>) and statistical analysis.

Treatment	Julian Date							
	189	203	217	231	245	259	273	
Control	31.66	48.36	55.20	52.90	23.84	56.97	14.56	
12 oz/a/wk	21.27	49.25	49.05	61.75	29.45	53.35	13.00	
48 oz/a/wk	34.36	43.43	58.09	48.34	29.76	61.83	13.13	
Treatment	NS	NS	NS	NS	NS	NS	NS	

NS = Not Significant

Table 5. Bermudagrass leaf nitrogen concentrations (%) and statistical analysis.

	Julian date						
Treatment	189	203	217	231	245	259	273
Control	3.48	3.30	3.55	3.48	4.35	3.30	3.85
12 oz/a/wk	3.45	3.40	3.50	3.40	4.33	3.40	4.03
48 oz/a/wk	3.43	3.33	3.60	3.48	4.38	3.28	3.98
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 6. Bermudagrass leaf phosphorus concentrations (%) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	0.31	0.32	0.29	0.30	0.33	0.29	0.29
12 oz/a/wk	0.31	0.32	0.30	0.28	0.33	0.28	0.32
48 oz/a/wk	0.29	0.34	0.32	0.30	0.35	0.27	0.30
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 7. Bermudagrass leaf potassium concentrations (%) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	0.91	1.03	0.98	1.08	1.07	1.08	0.95
12 oz/a/wk	0.88	0.97	0.99	0.99	1.02	1.08	1.08
48 oz/a/wk	0.85	1.07	1.09	1.02	1.14	0.95	0.96
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 8. Bermudagrass leaf calcium concentrations (%) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	0.71	0.62	0.49	0.54	0.55	0.53	0.76
12 oz/a/wk	0.76	0.57	0.50	0.58	0.60	0.52	0.74
48 oz/a/wk	0.74	0.60	0.54	0.51	0.52	0.57	0.74
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 9. Bermudagrass leaf magnesium concentrations (%) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	0.14	0.13	0.12	0.13	0.14	0.12	0.16
12 oz/a/wk	0.15	0.13	0.12	0.12	0.14	0.11	0.16
48 oz/a/wk	0.14	0.13	0.13	0.12	0.14	0.11	0.16
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 10. Bermudagrass leaf sulfur concentrations (%) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	0.33	0.36	0.29	0.33	0.36	0.33	0.33
12 oz/a/wk	0.34	0.34	0.30	0.33	0.36	0.32	0.35
48 oz/a/wk	0.32	0.37	0.33	0.31	0.37	0.31	0.32
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 11. Bermudagrass leaf sodium concentrations (%) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	0.24	0.28	0.26	0.18	0.10	0.13	0.19
12 oz/a/wk	0.21	0.27	0.27	0.15	0.10	0.13	0.19
48 oz/a/wk	0.23	0.33	0.30	0.18	0.12	0.12	0.19
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 12. Bermudagrass leaf boron concentrations (ppm) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	46.8	49.8	41.5	45.0	51.8	44.0	46.5
12 oz/a/wk	47.8	48.8	42.8	44.5	50.3	46.3	46.3
48 oz/a/wk	44.5	52.3	46.8	43.8	50.8	45.3	48.3
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 13. Bermudagrass leaf copper concentrations (ppm) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	10.2	10.2	7.5	9.0	10.5	8.2	12.3
12 oz/a/wk	10.9	10.1	7.7	8.3	10.5	8.0	11.8
48 oz/a/wk	10.1	10.5	8.7	8.7	11.0	7.5	10.5
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 14. Bermudagrass leaf iron concentrations (ppm) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	453	320	203	315	743	385	1800
12 oz/a/wk	683	285	208	253	765	303	1563
48 oz/a/wk	498	270	250	323	670	348	1633
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 15. Bermudagrass leaf manganese concentrations (ppm) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	137	86	72	76	78	67	120
12 oz/a/wk	136	62	60	59	73	54	109
48 oz/a/wk	102	74	68	67	72	63	107
Treatment	NS	NS	NS	NS	NS	NS	NS

NS = Not Significant

Table 16. Bermudagrass leaf zinc concentrations (ppm) and statistical analysis.

	Julian Date						
Treatment	189	203	217	231	245	259	273
Control	36.0	35.3	41.8	47.5a	38.3	34.3	62.5
12 oz/a/wk	37.5	39.5	37.5	36.0b	40.0	35.8	61.5
48 oz/a/wk	35.5	47.3	41.5	49.8a	39.3	41.3	42.5
Treatment	NS	NS	NS	**	NS	NS	NS

NS = Not Significant

\*\* = significant at  $p = 0.01$ ; numbers in a column followed by different letters are statistically different.

Figure 1. Soil nitrate-nitrogen levels (ppm).

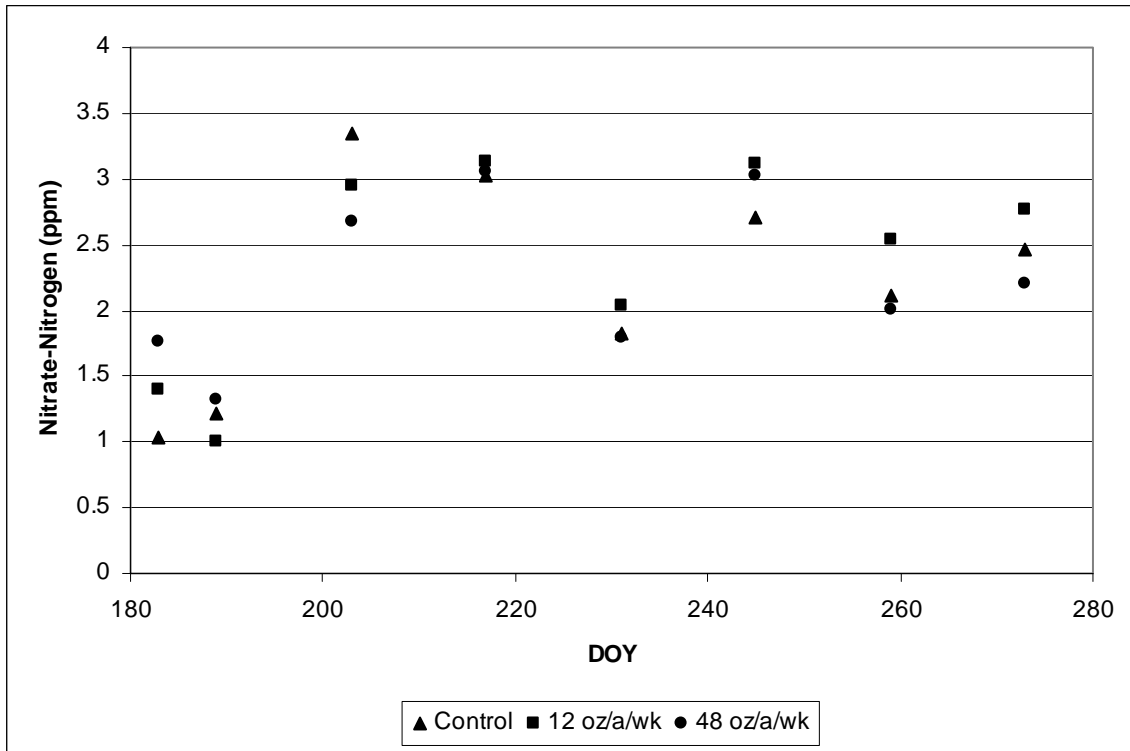


Figure 2. Soil ammonium-nitrogen levels (ppm).

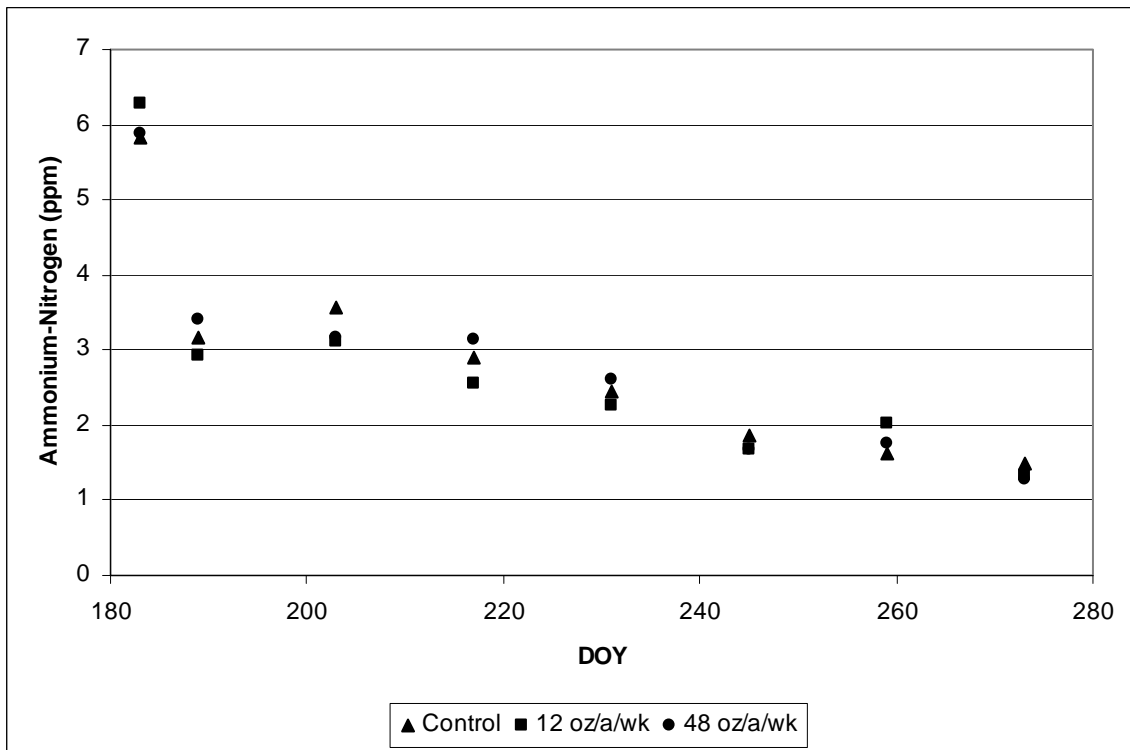


Figure 3. Dry weights of bermudagrass clippings ( $\text{g}/\text{m}^2$ ).

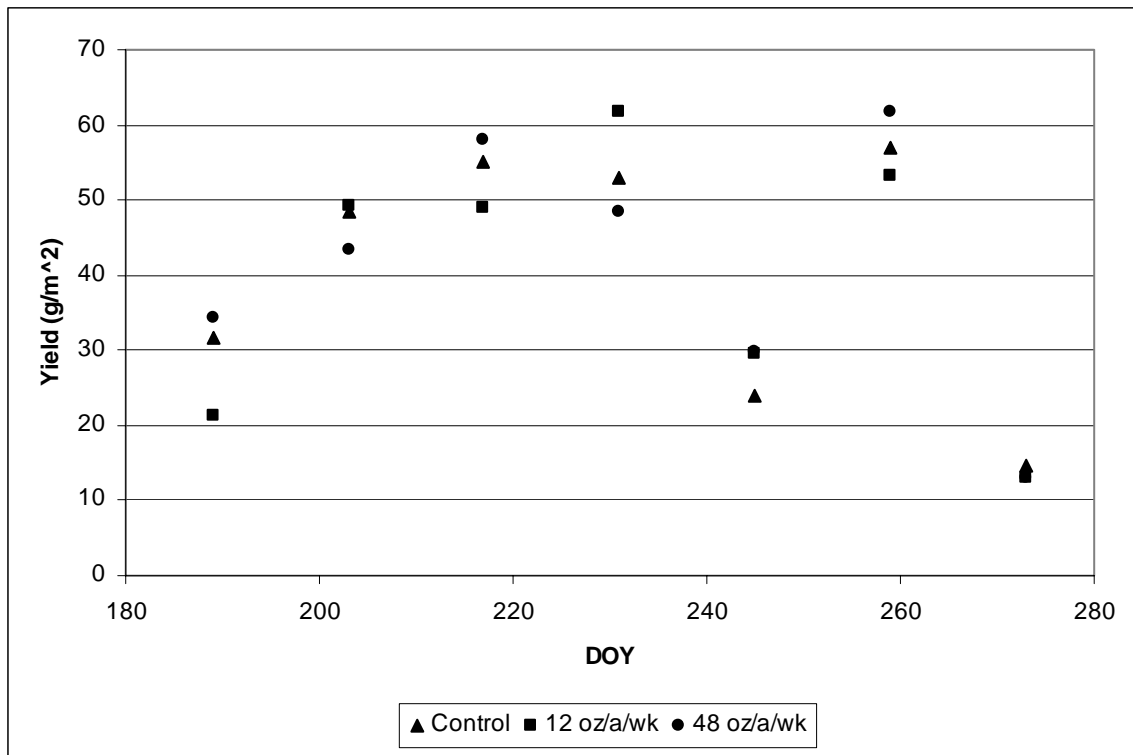


Figure 4. Bermudagrass leaf nitrogen concentrations (%).

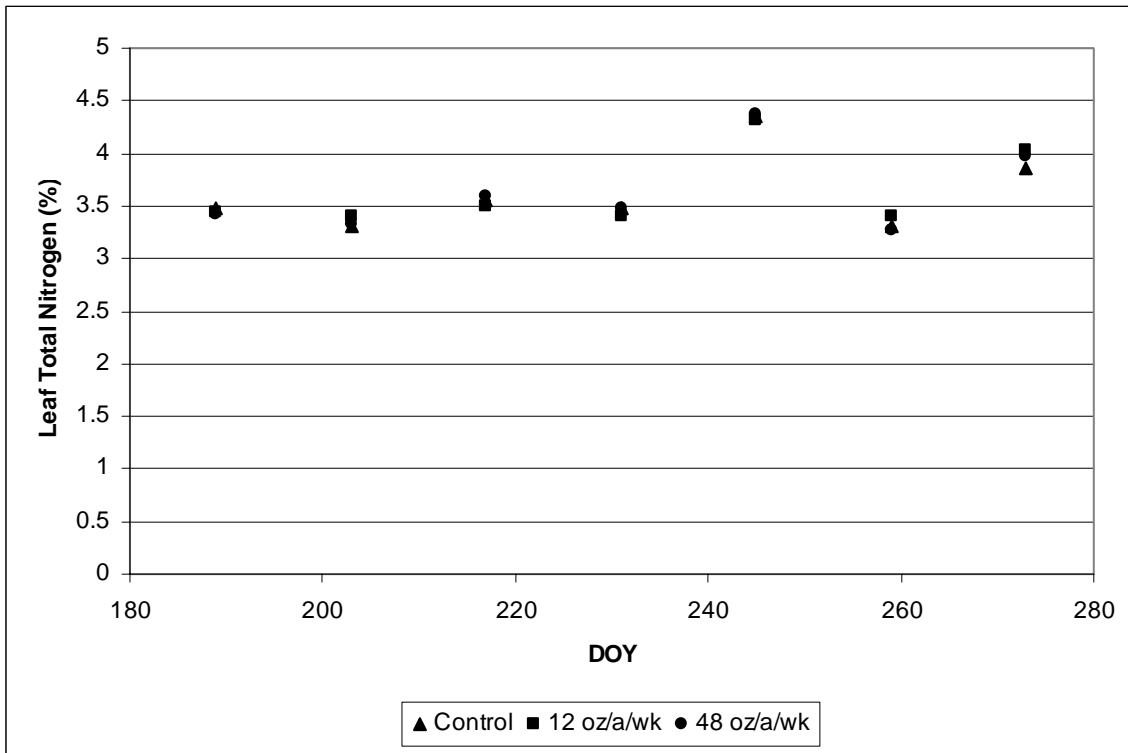


Figure 5. Bermudagrass leaf phosphorus concentrations (%).

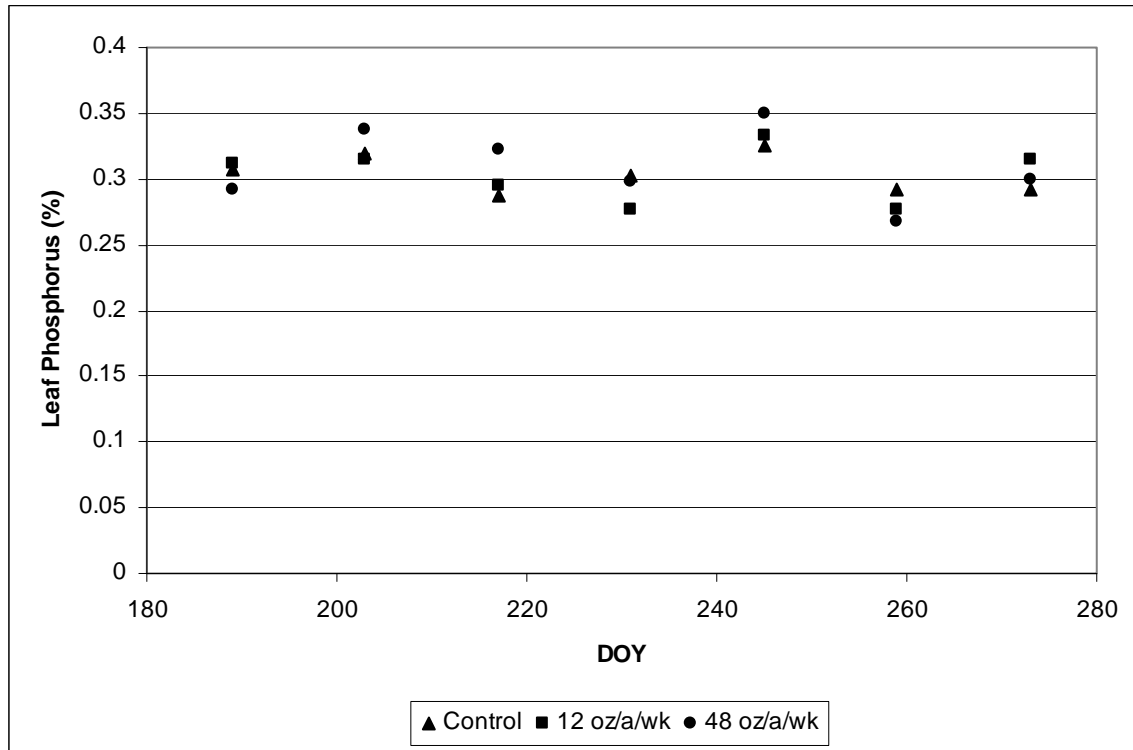


Figure 6. Bermudagrass leaf potassium concentrations (%).

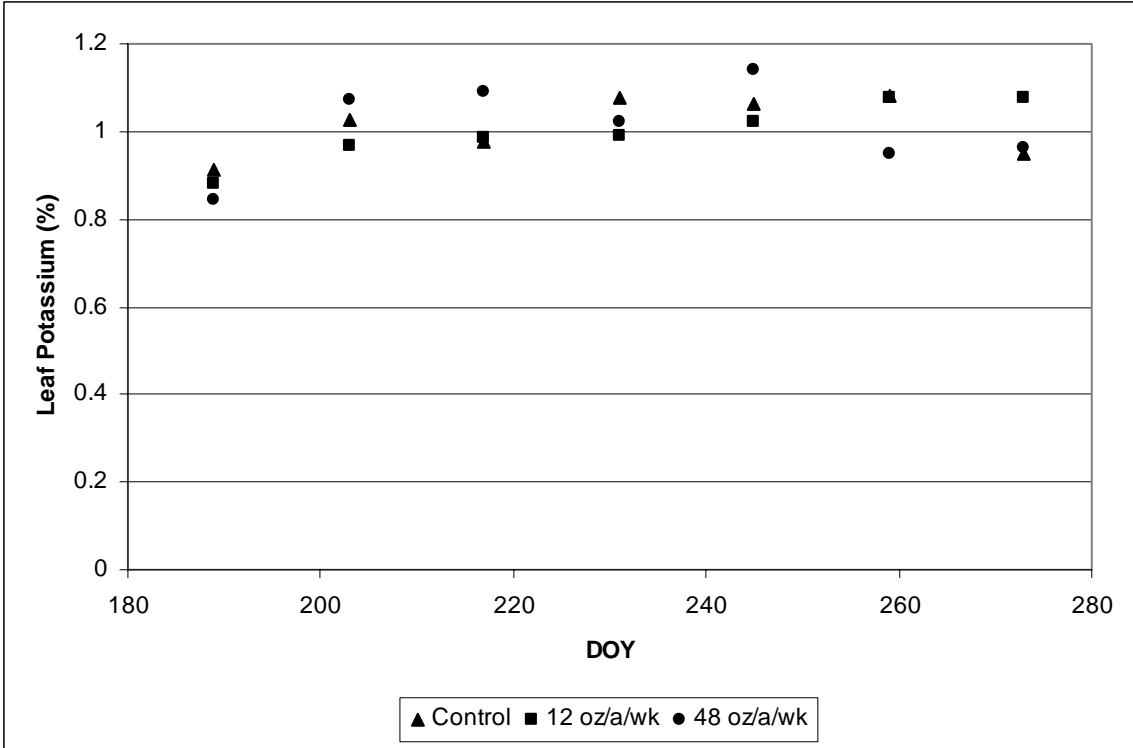


Figure 7. Bermudagrass leaf tissue calcium concentrations (%).

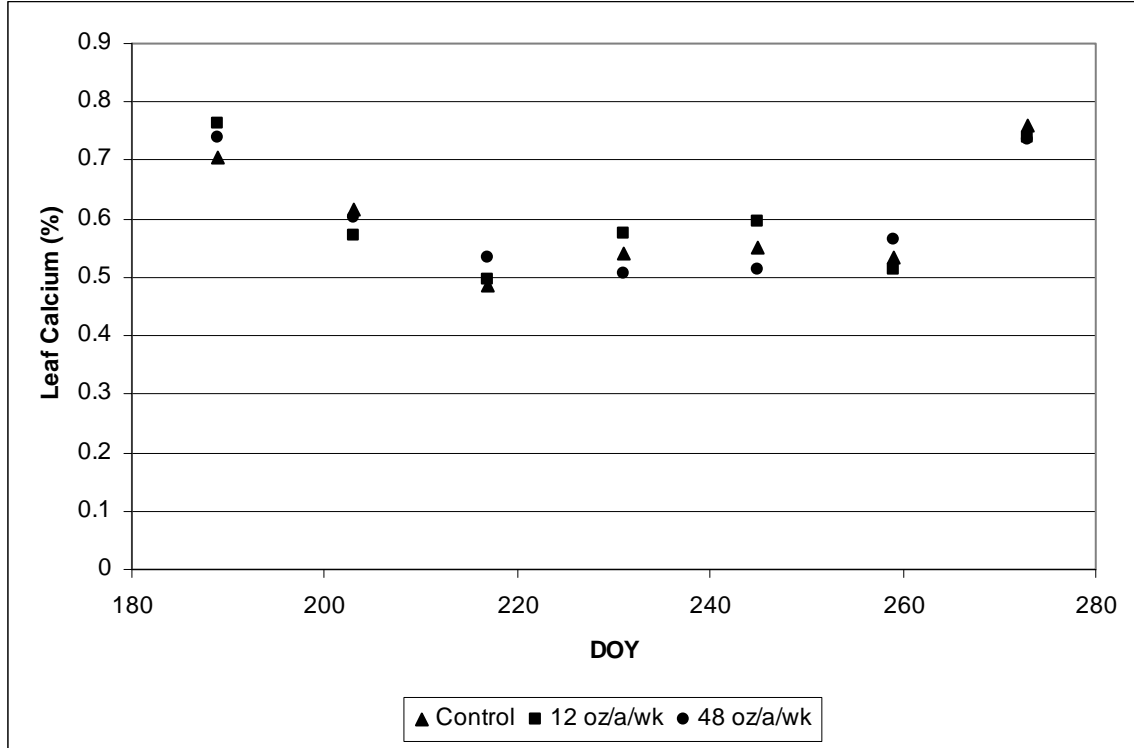


Figure 8. Bermudagrass leaf tissue magnesium concentrations (%).

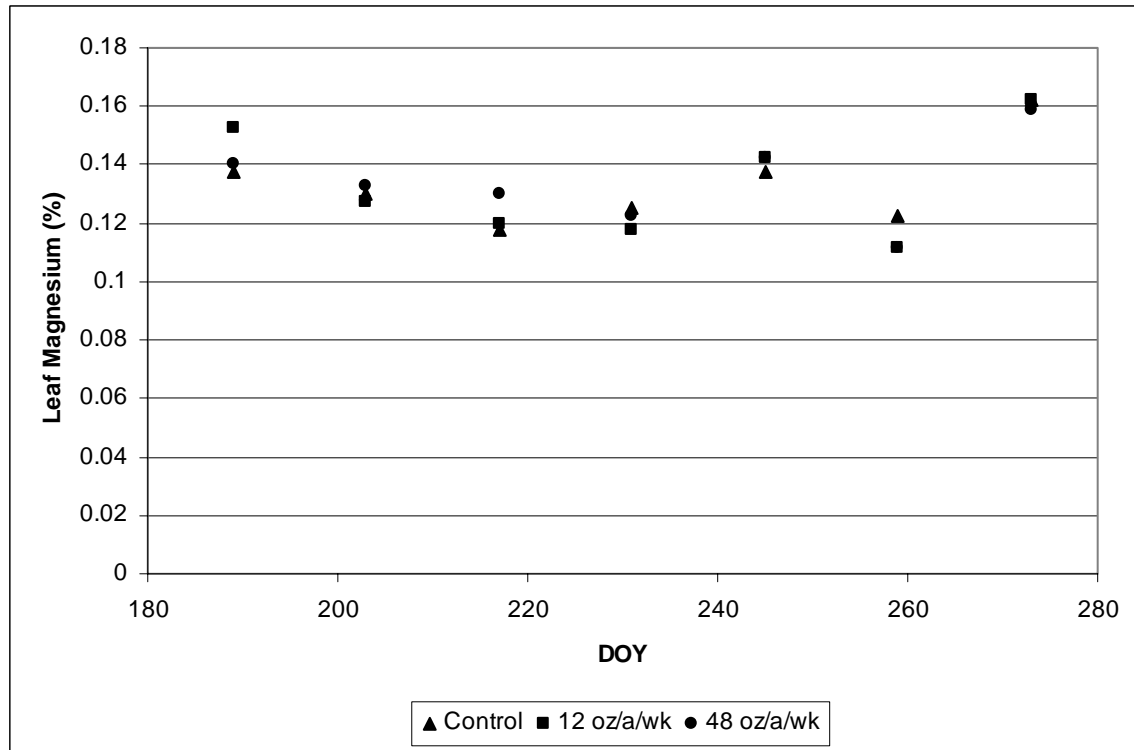


Figure 9. Bermudagrass leaf tissue sulfur concentrations (%).

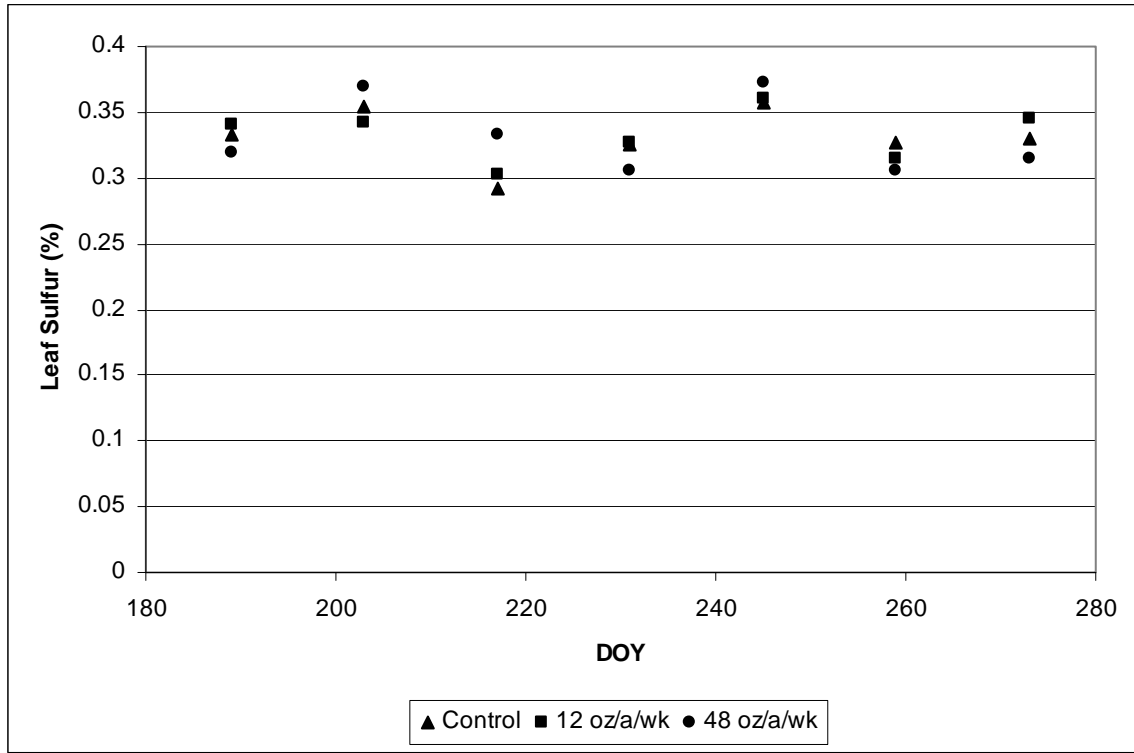


Figure 10. Bermudagrass leaf tissue sodium concentrations (%).

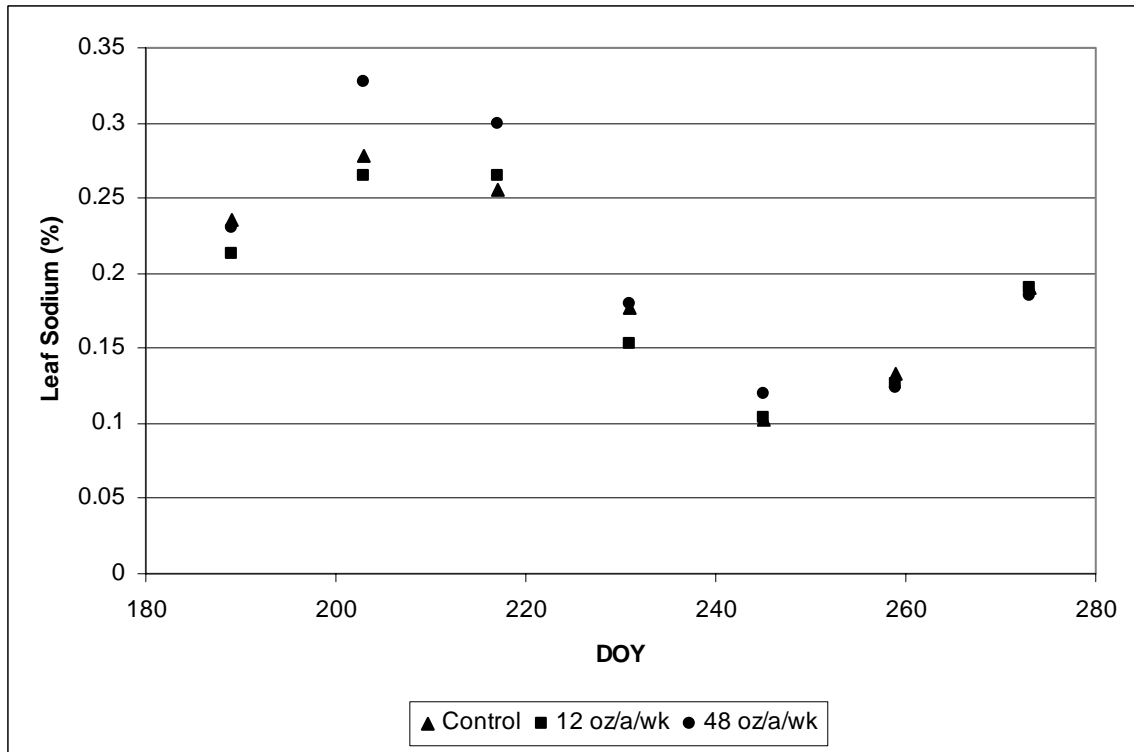


Figure 11. Bermudagrass leaf tissue boron concentrations (ppm).

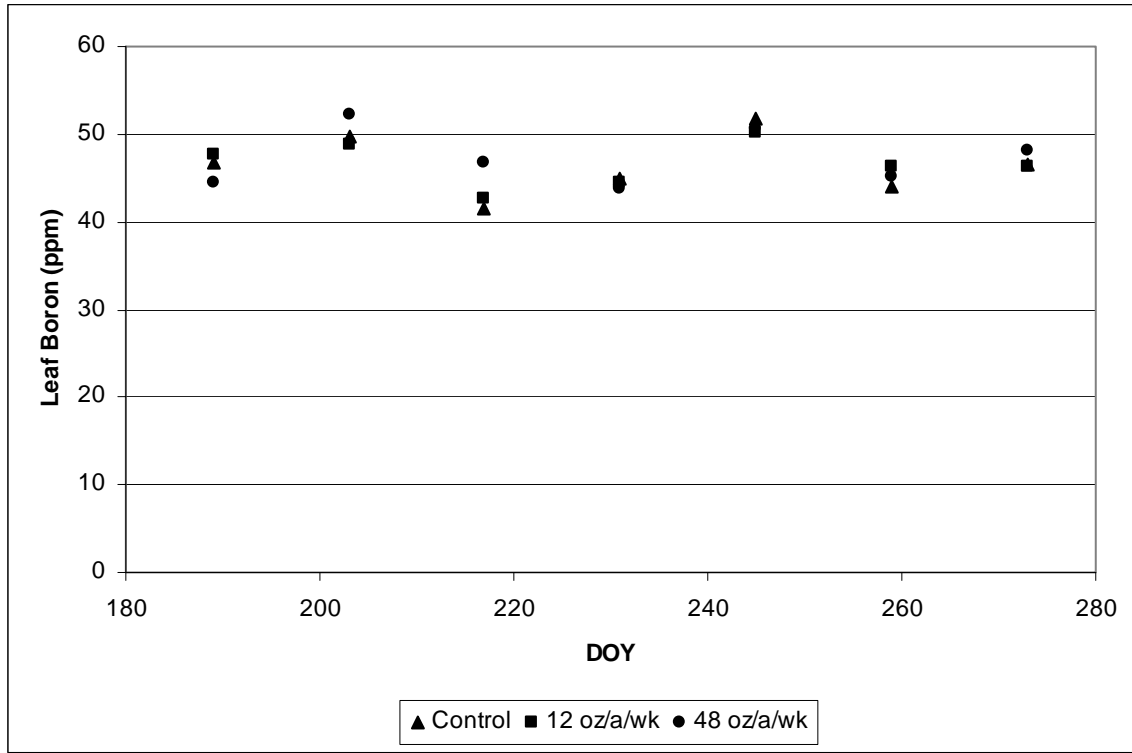


Figure 12. Bermudagrass leaf tissue copper concentrations (ppm).

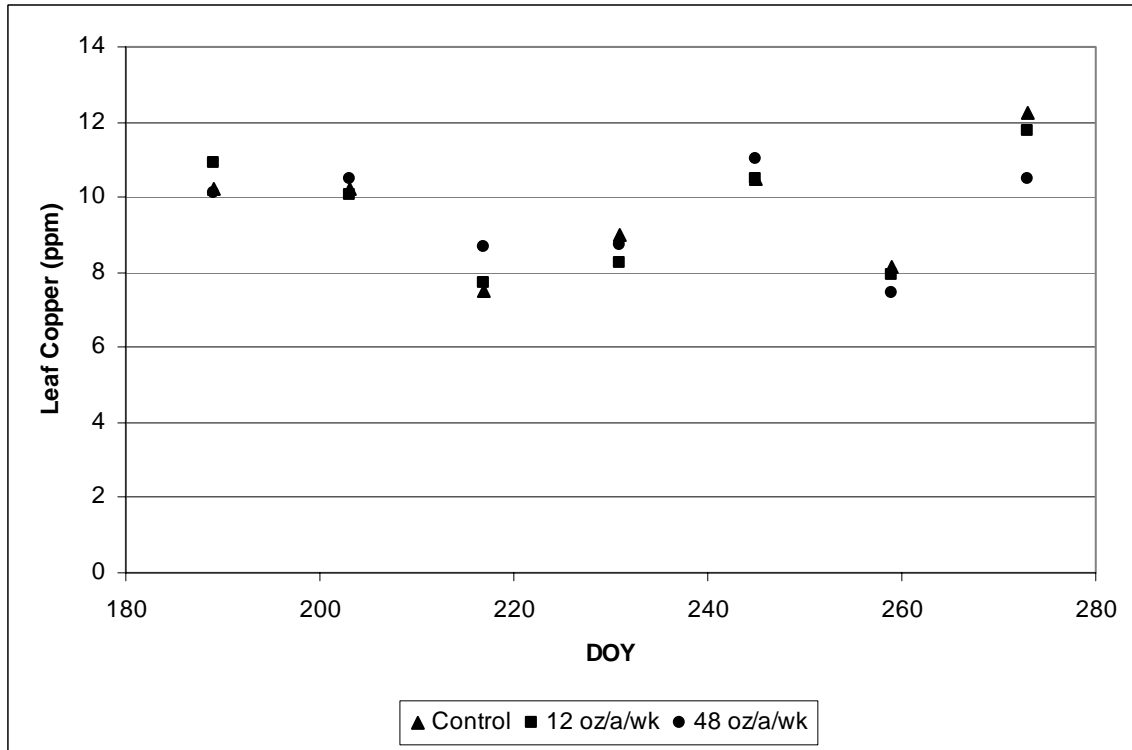


Figure 13. Bermudagrass leaf tissue iron concentrations (ppm).

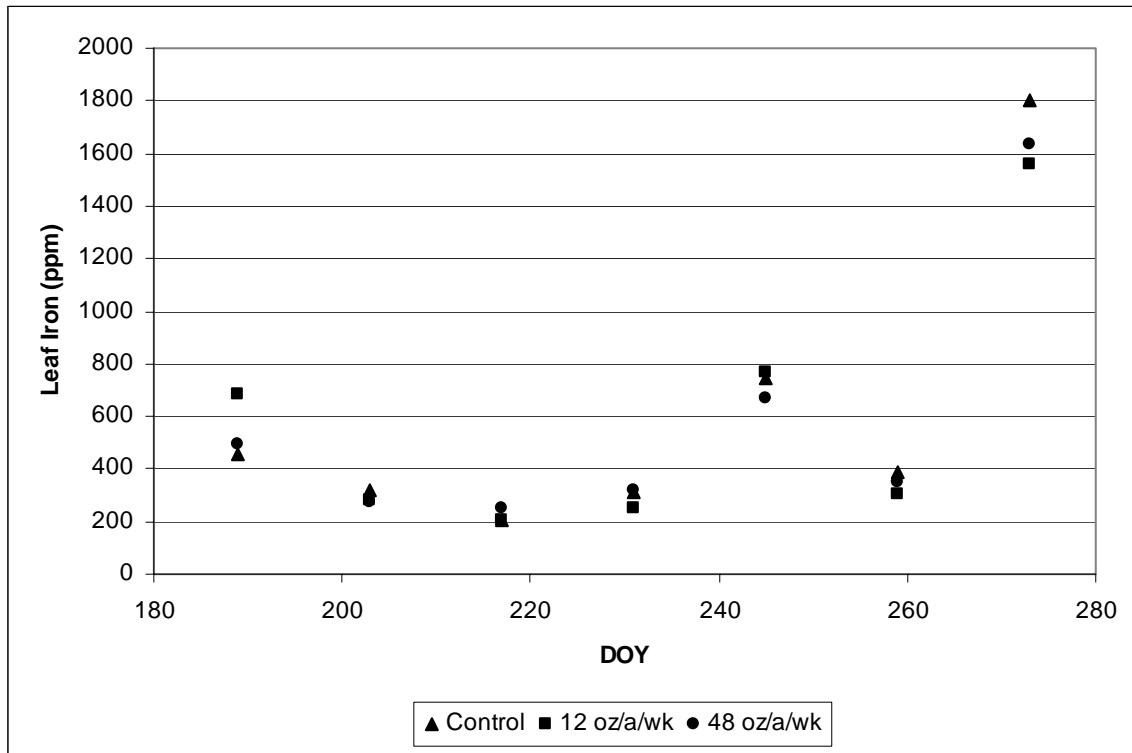


Figure 14. Bermudagrass leaf tissue manganese concentrations (ppm).

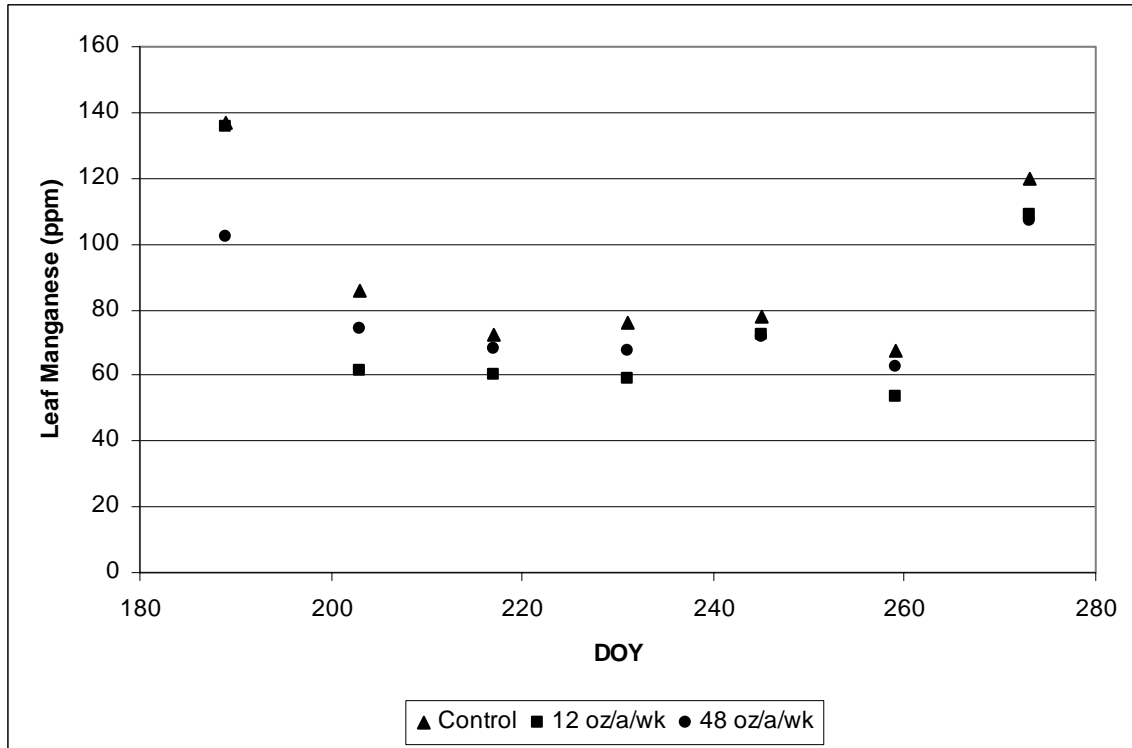


Figure 15. Bermudagrass leaf tissue zinc concentrations (ppm).

